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(54) **CONTROL APPARATUS**

(71) Applicant: **BROTHER KOGYO KABUSHIKI KAISHA**, Nagoya-shi, Aichi-ken (JP)

(72) Inventor: **Kenichi Iesaki**, Ichinomiya (JP)

(73) Assignee: **BROTHER KOGYO KABUSHIKI KAISHA**, Nagoya-Shi, Aichi-Ken (JP)

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B65H 7/20 (2006.01)
B65H 5/06 (2006.01)
B65H 7/08 (2006.01)

(52) **U.S. Cl.**
CPC ***B65H 7/20*** (2013.01); ***B65H 5/062*** (2013.01); ***B65H 7/08*** (2013.01); *B65H 2511/20* (2013.01); *B65H 2511/212* (2013.01); *B65H 2513/11* (2013.01); *B65H 2553/51* (2013.01); *B65H 2557/24* (2013.01)

(58) **Field of Classification Search**
CPC B65H 7/20; B65H 5/00; B65H 5/06; B65H 7/02; B65H 5/062; B65H 7/00; B65H 29/125; B65H 43/00; B65H 2553/51
See application file for complete search history.

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Primary Examiner — David H Bollinger
(74) *Attorney, Agent, or Firm* — Merchant & Gould P.C.

(57) **ABSTRACT**

A control apparatus includes: a motor; a driving body rotated by the motor; rotary encoder including a disk and a sensor; a detector detecting a rotation position and a rotation velocity of the disk based on a signal outputted from the sensor; and a controller. The disk is fixed to the driving body in a state of being eccentric to a rotational axis of the driving body, and the sensor reads a scale of the disk and outputs a pulse signal depending on rotation of the disk. The controller generates velocity data indicating a locus of the rotation velocity with respect to the rotation position; specifies a position-phase relation between the rotation position of the disk and a rotation phase of the driving body; and controls at least one of the rotation of the driving body and displacement of an object being displaced by action from the driving body.

11 Claims, 10 Drawing Sheets

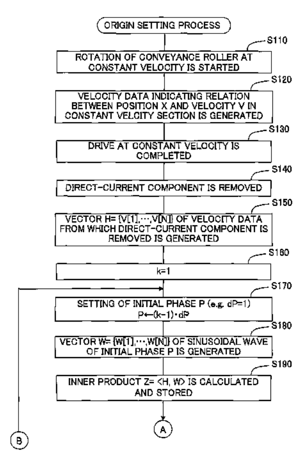


Fig. 1

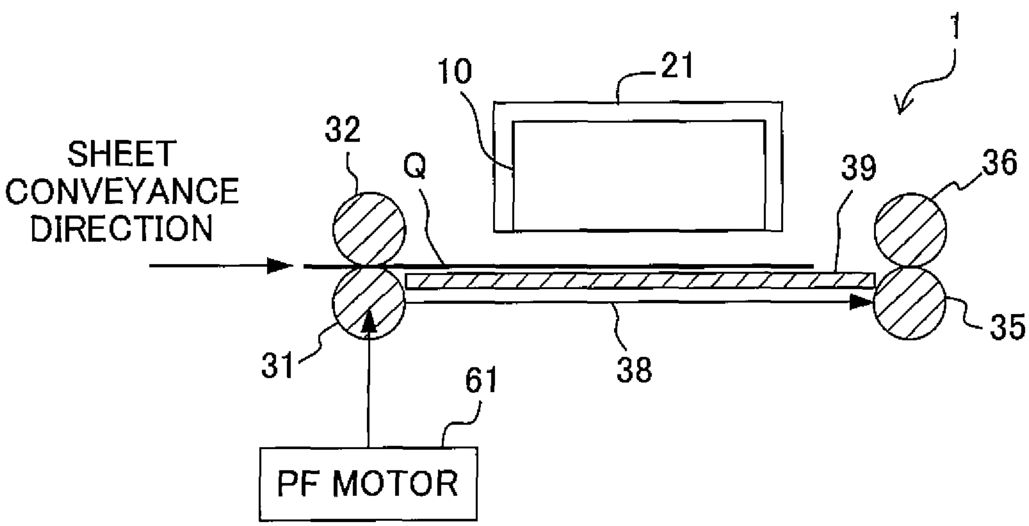

1
10
21
32
Q
SHEET
CONVEYANCE
DIRECTION
39
36
31
61
38
35
PF MOTOR

Fig. 2

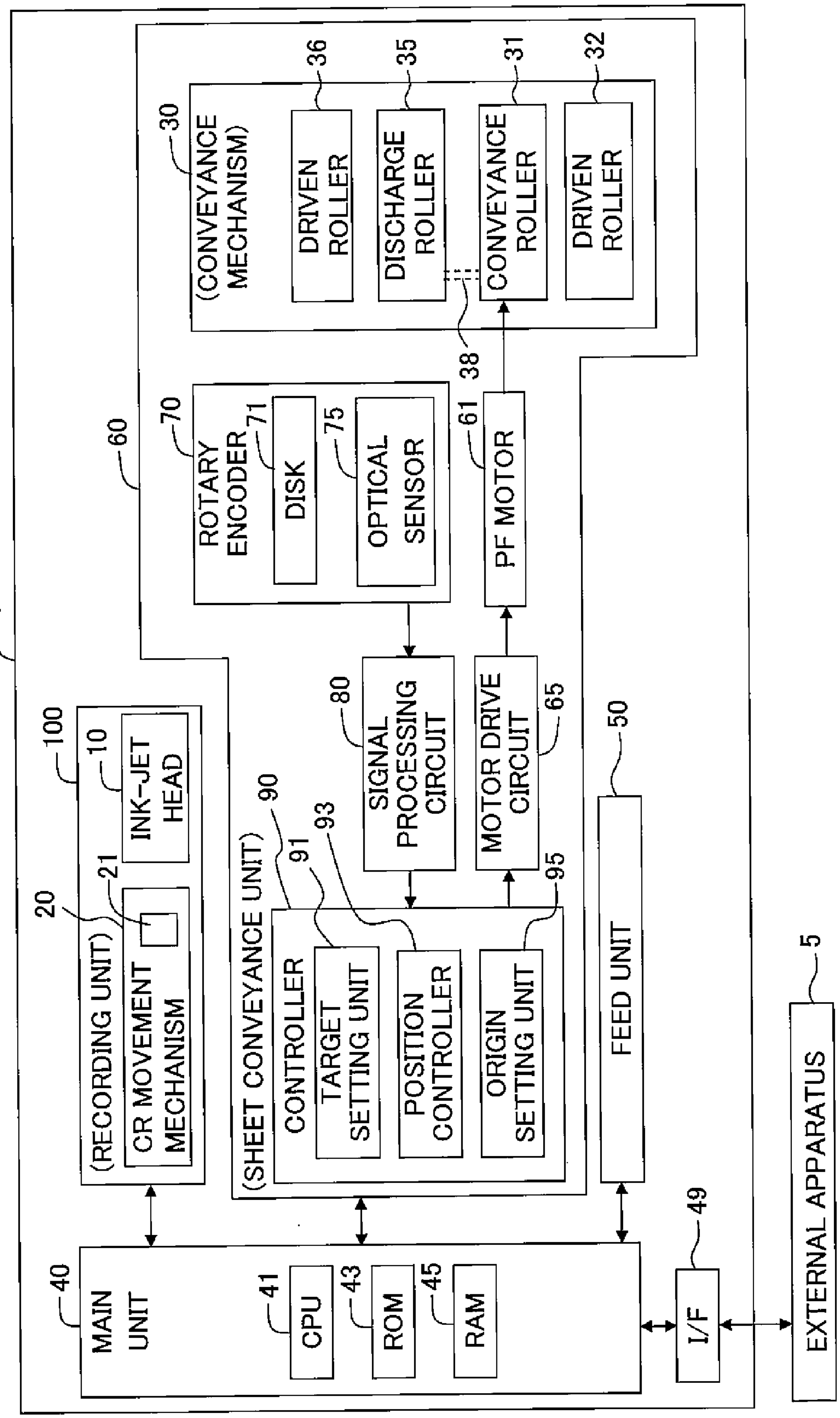

1
MAIN UNIT
40
CPU
41
ROM
43
RAM
45
I/F
49
EXTERNAL APPARATUS
5
(RECORDING UNIT)
100
CR MOVEMENT MECHANISM
20
21
INK-JET HEAD
10
(SHEET CONVEYANCE UNIT)
60
CONTROLLER
90
TARGET SETTING UNIT
91
POSITION CONTROLLER
93
ORIGIN SETTING UNIT
95
SIGNAL PROCESSING CIRCUIT
80
MOTOR DRIVE CIRCUIT
65
FEED UNIT
50
ROTARY ENCODER
70
DISK
71
OPTICAL SENSOR
75
PF MOTOR
61
(CONVEYANCE MECHANISM)
30
DRIVEN ROLLER
36
DISCHARGE ROLLER
35
CONVEYANCE ROLLER
31
DRIVEN ROLLER
32
38

Fig. 3

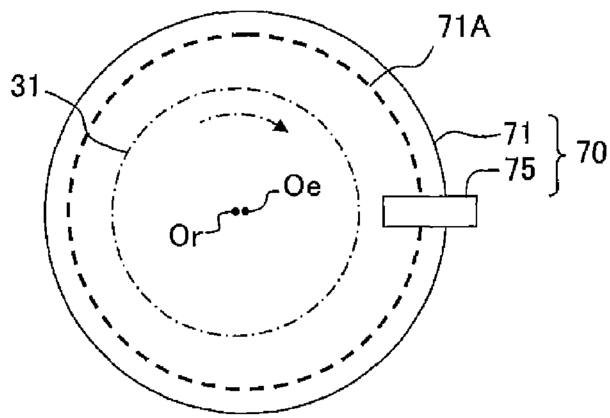

71A
31
71
75
70
Oe
Or

Fig. 4

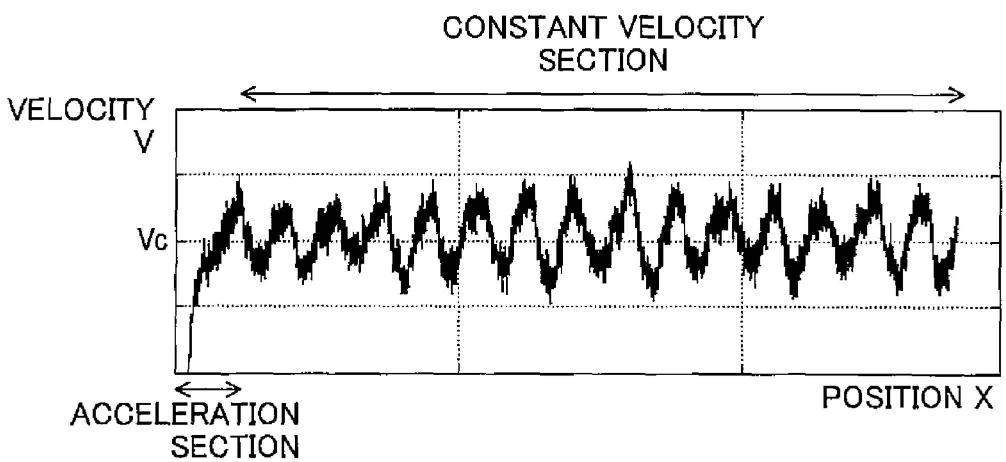

CONSTANT VELOCITY SECTION
VELOCITY V
Vc
ACCELERATION SECTION
POSITION X

Fig. 5

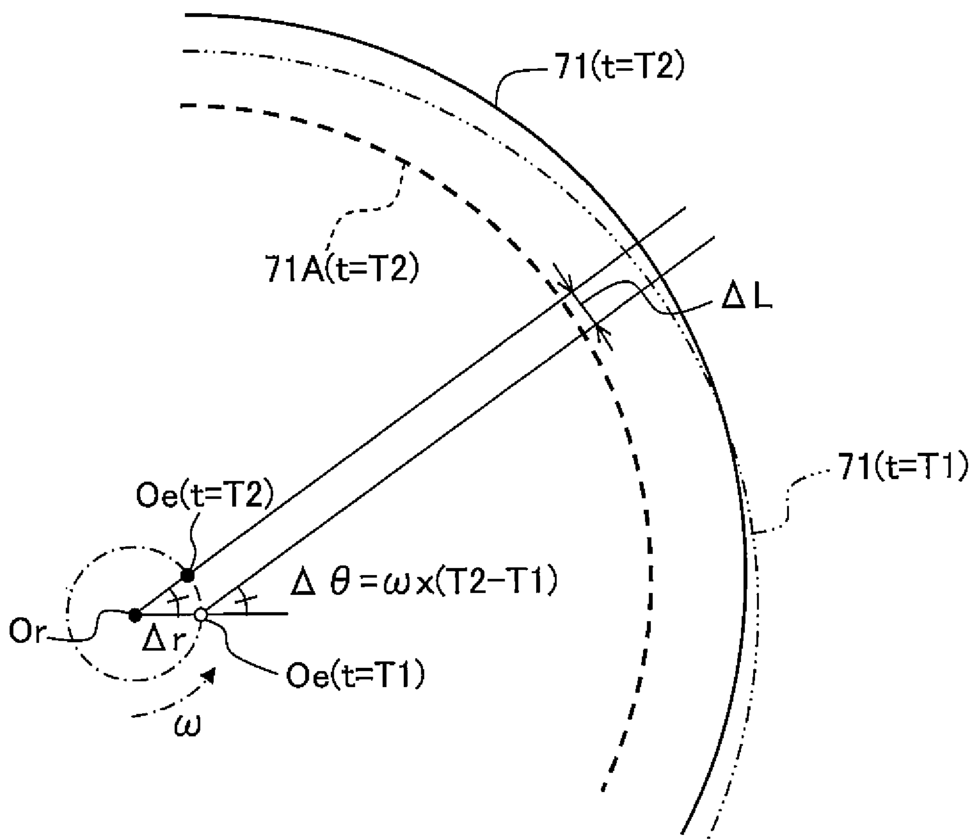


Fig. 6A

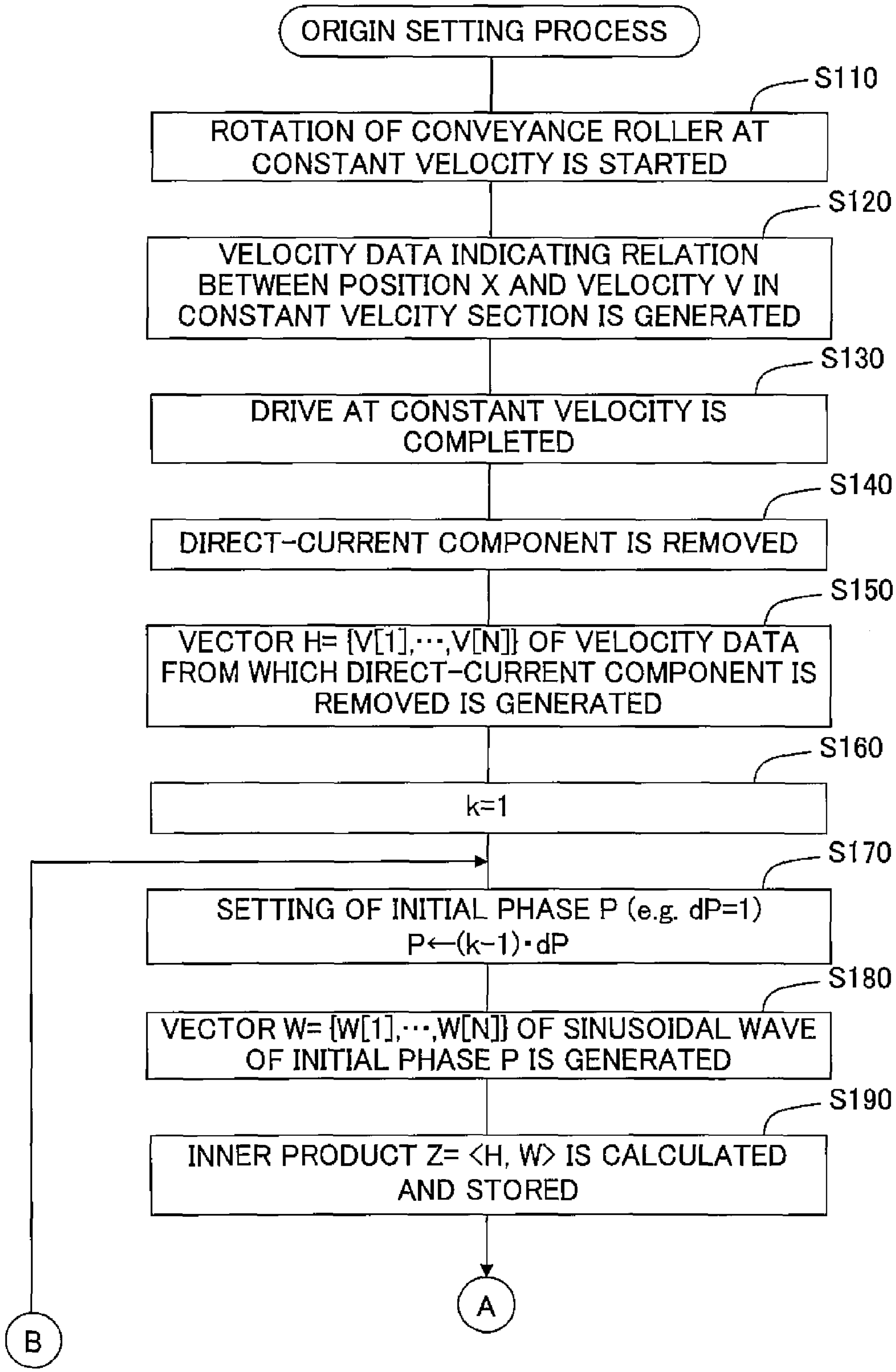

ORIGIN SETTING PROCESS
S110
ROTATION OF CONVEYANCE ROLLER AT CONSTANT VELOCITY IS STARTED
S120
VELOCITY DATA INDICATING RELATION BETWEEN POSITION X AND VELOCITY V IN CONSTANT VELCITY SECTION IS GENERATED
S130
DRIVE AT CONSTANT VELOCITY IS COMPLETED
S140
DIRECT-CURRENT COMPONENT IS REMOVED
S150
VECTOR H= {V[1],···,V[N]} OF VELOCITY DATA FROM WHICH DIRECT-CURRENT COMPONENT IS REMOVED IS GENERATED
S160
k=1
S170
SETTING OF INITIAL PHASE P (e.g. dP=1)
P←(k-1)·dP
S180
VECTOR W= {W[1],···,W[N]} OF SINUSOIDAL WAVE OF INITIAL PHASE P IS GENERATED
S190
INNER PRODUCT Z= <H, W> IS CALCULATED AND STORED
A
B

Fig. 6B

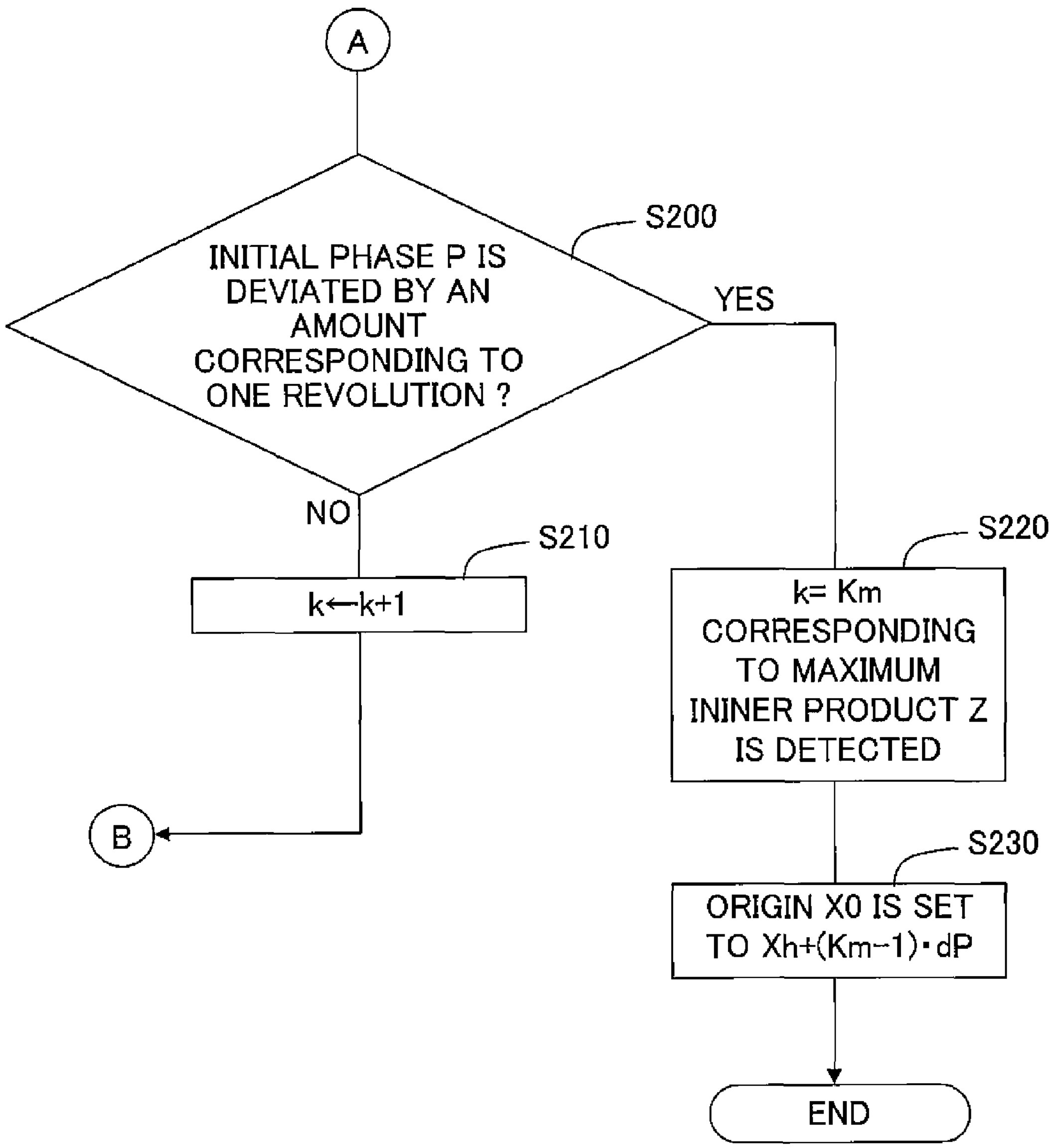

A
INITIAL PHASE P IS DEVIATED BY AN AMOUNT CORRESPONDING TO ONE REVOLUTION ?
S200
YES
NO
S210
k←k+1
B
S220
k= Km CORRESPONDING TO MAXIMUM ININER PRODUCT Z IS DETECTED
S230
ORIGIN X0 IS SET TO Xh+(Km−1)·dP
END

Fig. 7A

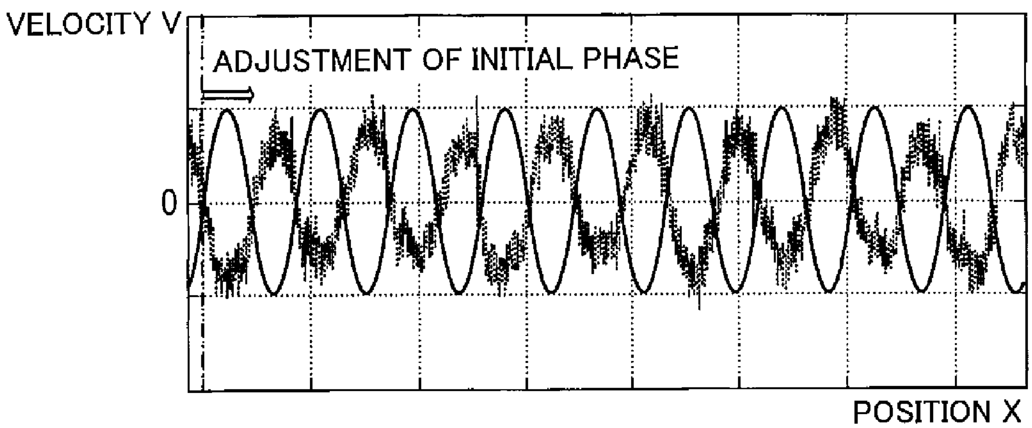

VELOCITY V
ADJUSTMENT OF INITIAL PHASE
0
POSITION X

Fig. 7B

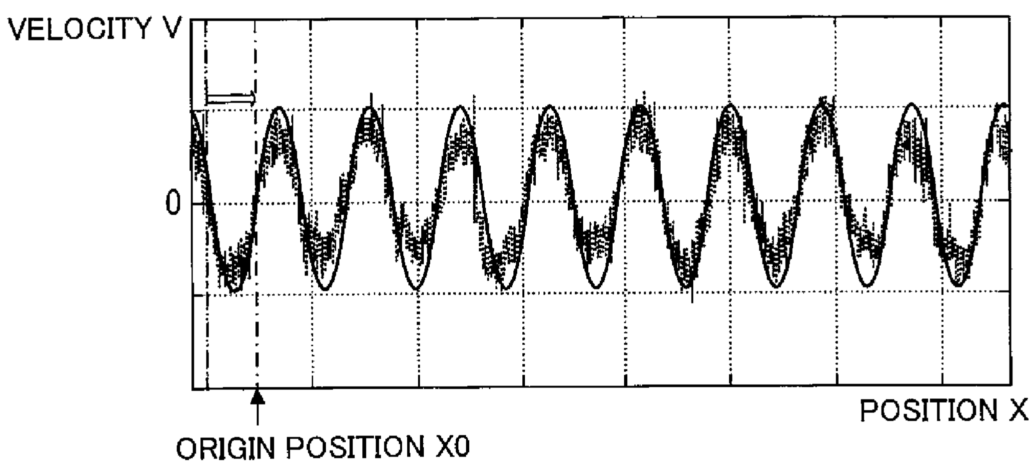

VELOCITY V
0
POSITION X
ORIGIN POSITION X0

Fig. 8A

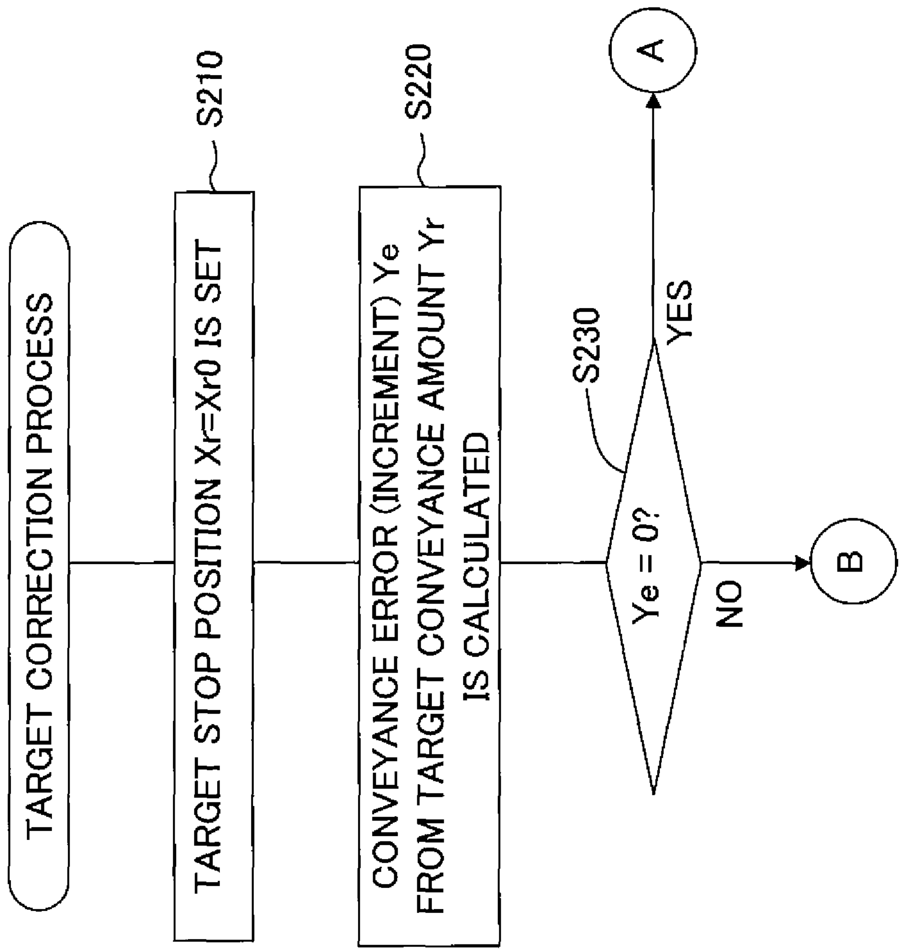

TARGET CORRECTION PROCESS
S210
TARGET STOP POSITION Xr=Xr0 IS SET
S220
CONVEYANCE ERROR (INCREMENT) Ye FROM TARGET CONVEYANCE AMOUNT Yr IS CALCULATED
S230
Ye = 0?
YES
A
NO
B

Fig. 8B

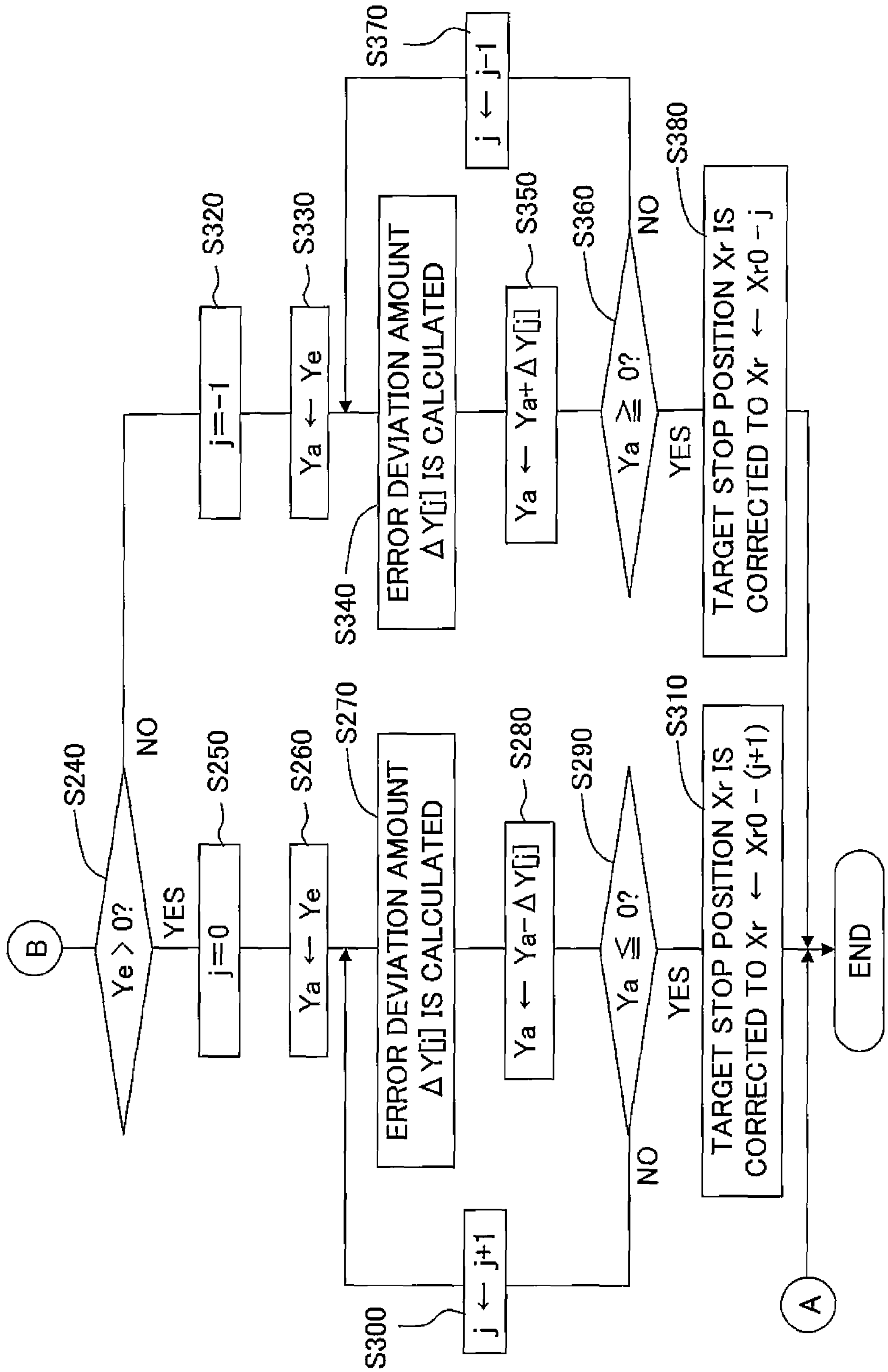
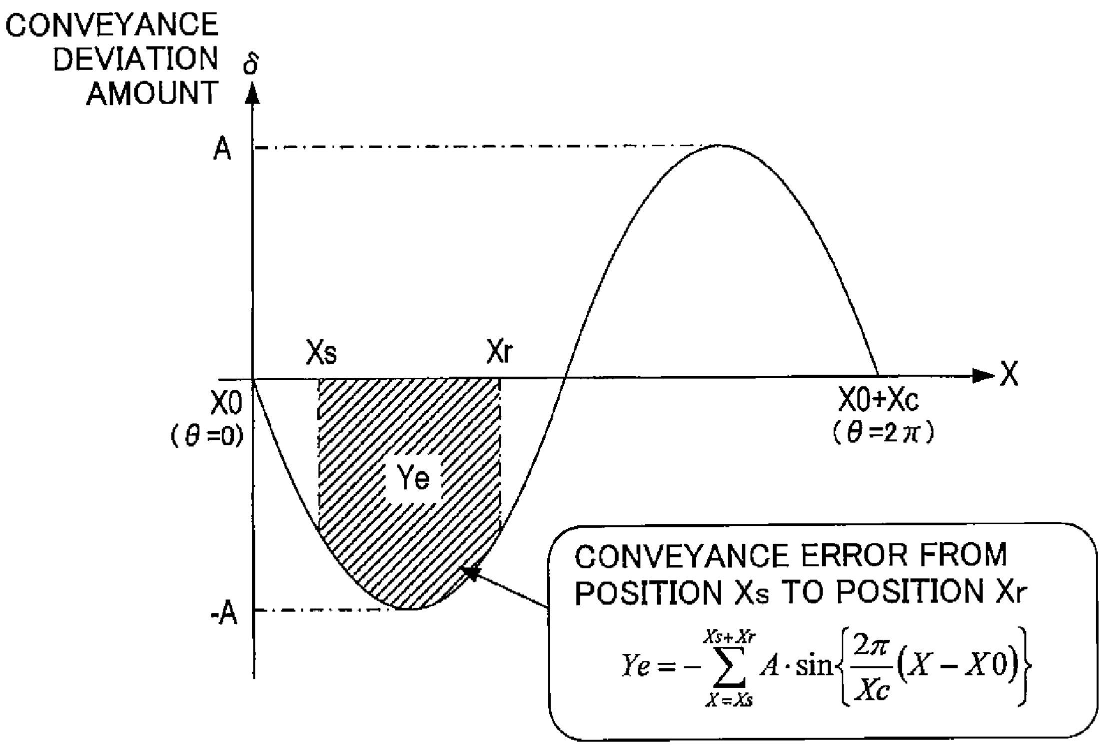

B
Ye > 0?
S240
YES
NO
j=0
S250
Ya ← Ye
S260
ERROR DEVIATION AMOUNT ΔY[j] IS CALCULATED
S270
Ya ← Ya−ΔY[j]
S280
Ya ≦ 0?
S290
YES
NO
j ← j+1
S300
TARGET STOP POSITION Xr IS CORRECTED TO Xr ← Xr0 − (j+1)
S310
j=−1
S320
Ya ← Ye
S330
ERROR DEVIATION AMOUNT ΔY[j] IS CALCULATED
S340
Ya ← Ya+ΔY[j]
S350
Ya ≧ 0?
S360
YES
NO
j ← j−1
S370
TARGET STOP POSITION Xr IS CORRECTED TO Xr ← Xr0 − j
S380
END
A

Fig. 9


CONVEYANCE DEVIATION AMOUNT
δ
A
-A
Xs
Xr
X
X0
(θ=0)
X0+Xc
(θ=2π)
Ye
CONVEYANCE ERROR FROM POSITION Xs TO POSITION Xr
$Ye = -\sum_{X=Xs}^{Xs+Xr} A \cdot \sin\left\{\frac{2\pi}{Xc}(X - X0)\right\}$

CONTROL APPARATUS

CROSS REFERENCE TO RELATED APPLICATION

The present application claims priority from Japanese Patent Application No. 2014-072519, filed on Mar. 31, 2014, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND

1. Field of the Invention

The present teaching relates to a control apparatus.

2. Description of the Related Art

There is conventionally known a conveyance system which conveys a sheet by rotation of rollers. Further, there is known a system which detects the origin of rotation phase θ of the roller in order to achieve high-accuracy sheet conveyance. For example, in a case that the roller has eccentricity, the conveyance amount of the sheet varies depending on the rotation phase θ ($0 \leq \theta < 2\pi$) at the time of conveyance. Therefore, the high-accuracy sheet conveyance is achieved by detecting the origin of the rotation phase θ and controlling rotation of the roller while taking the rotation phase θ into account.

SUMMARY

According to an aspect of the present teaching, there is provided a control apparatus including: a motor; a driving body configured to rotate around a rotational axis by the motor; a rotary encoder including a disk and a sensor, the disk being fixed to the driving body in a state of being eccentric to the rotational axis of the driving body; and being configured to rotate with the driving body, and the sensor being configured to read a scale of the disk and to output a pulse signal depending on rotation of the disk; a detector configured to detect a rotation position and a rotation velocity of the disk based on the pulse signal outputted from the sensor; and a controller, wherein the controller is configured to perform: a data generation process of controlling the motor to make the driving body turn at least one rotation and generating velocity data based on the rotation position and the rotation velocity which are detected by the detector during the at least one rotation of the driving body, the velocity data indicating a locus of the rotation velocity with respect to the rotation position; a phase specifying process of specifying a position-phase relation, which is a correspondence relation between the rotation position of the disk and a rotation phase of the driving body, by detecting a phase, of a periodic velocity component of the locus indicated by the velocity data, with respect to the rotation position, the periodic velocity component corresponding to a rotation period of the driving body; and a main control process of controlling at least one of the rotation of the driving body and displacement of an object, which is displaced by action from the driving body, by driving the motor based on the position-phase relation specified by the phase specifying process.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic cross sectional view of the periphery of a sheet conveyance mechanism of an image forming system.

FIG. **2** is a block diagram depicting an electrical configuration of the image forming system.

FIG. **3** depicts an arrangement of a disk and an optical sensor provided for a rotary encoder.

FIG. **4** is a graph indicating rotation positions and rotational velocities observed by the rotary encoder.

FIG. **5** depicts a displacement of a scale which is caused by a displacement of the center of the disk.

FIGS. **6**A and **6**B depict a flowchart indicating an origin setting process executed by an origin setting unit.

FIGS. **7**A and **7**B are illustrative views each illustrating a search aspect of a sinusoidal wave which matches a velocity locus, FIG. **7**A depicts a sinusoidal wave before the search and FIG. **7**B depicts a sinusoidal wave having a phase which matches the searched velocity locus.

FIGS. **8**A and **8**B depict a flowchart indicating a target correction process executed by a target setting unit.

FIG. **9** is an illustrative view illustrating an amount of deviation of conveyance.

DESCRIPTION OF THE EMBODIMENTS

Hereinbelow, an embodiment of the present teaching will be explained with reference to the drawings. An image forming system **1** of this embodiment depicted in FIG. **1** is an ink-jet printer including a platen **39** on which a sheet Q passes and an ink jet head **10**.

The ink-jet head **10** is disposed above the platen **39** in a state of being carried on a carriage **21**. The ink-jet head **10** moves together with the carriage **21** in a main scanning direction (a direction orthogonal to the sheet surface of FIG. **1**) orthogonal to a sheet conveyance direction. The ink jet head **10** discharges ink droplets while moving in the main scanning direction to form an image in the main scanning direction on the sheet Q.

That is, the image forming system **1** conveys the sheet Q to a first image formation position, and then moves the carriage **21** at a constant velocity in the main scanning direction. In this situation, ink droplets are discharged by the ink jet head **10** carried on the carriage **21** to form the image in the main scanning direction. After that, the image forming system **1** conveys the sheet Q downstream in the sheet conveyance direction so that the sheet Q arrives at a second image formation position. The image forming system **1** forms the image over the entire sheet Q by performing the above operations repeatedly.

The sheet Q is conveyed from the upstream side to the downstream side of the platen **39** upon receiving the force which is generated by rotations of a conveyance roller **31** and a discharge roller **35**. The sheet conveyance direction is orthogonal to rotational axes of the conveyance roller **31** and the discharge roller **35**. The conveyance roller **31** is disposed to face a driven roller **32** at the upstream side of the platen **39**. The discharger roller **35** is disposed to face a driven roller **36** at the downstream side of the platen **39**.

The conveyance roller **31** rotates while nipping or holding the sheet Q between itself and the driven roller **32** to convey the sheet Q downstream. The conveyance roller **31** is rotationally driven by a PF motor **61** constructed of a direct-current motor. The discharge roller **35** rotates while nipping or holding the sheet Q between itself and the driven roller **36** to convey the sheet Q, which is conveyed along the platen **39** by the conveyance roller **31**, further downstream in the sheet conveyance direction.

The discharge roller **35** is connected to the conveyance roller **31** via a connection mechanism **38** (for example, a gear mechanism). The discharge roller **35** receives the power from the PF motor **61** via the conveyance roller **31** and the connection mechanism **38** to rotate in synchronization with the conveyance roller **31**. The conveyance roller **31**, the driven roller **32**, the discharge roller **35**, the driven roller **36**, the connection mechanism **38**, and the platen **39** constitute a conveyance mechanism **30** of the sheet Q (see FIG. **2**).

Subsequently, the detailed construction of the image forming system **1** will be explained. As depicted in FIG. **2**, the image forming system **1** is provided with a main unit **40**, a communication interface **49**, a feed unit **50**, a sheet conveyance unit **60**, and a recording unit **100**.

The main unit **40** includes a CPU **41**, a ROM **43**, and a RAM **45** and controls the image forming system **1** in an integrated manner. The CPU **41** executes processes in accordance with programs stored in the ROM **43**. The RAM **45** is used as a working memory when each of the processes is executed by the CPU **41**.

In a case that the main unit **40** has received data to be printed from an external apparatus **5** via the communication interface **49**, the main unit **40** inputs commands to the feed unit **50**, the sheet conveyance unit **60**, and the recording unit **100** to form the image based on the data to be printed on the sheet Q. The communication interface **49** is an interface such as a USB interface or a LAN interface which is capable of communicating with the external apparatus **5** such as a personal computer.

The feed unit **50** conveys the sheet Q from an unillustrated feed tray to a nip position of the sheet Q where the sheet Q is nipped between the conveyance roller **31** and the driven roller **32** in accordance with the command from the main unit **40**. The sheet conveyance unit **60** intermittently conveys the sheet Q supplied from the feed unit **50** to each image formation position in accordance with the command from the main unit **40**.

The recording unit **100** forms the image in the main scanning direction on the sheet Q at the timing at which the conveyance of the sheet Q by the sheet conveyance unit **60** is stopped. The recording unit **100** includes the ink-jet head **10**, the carriage **21**, and a carriage movement mechanism **20** which is capable of moving or reciprocating the carriage **21** in the main scanning direction.

Upon receipt of the command from the main unit **40** by the recording unit **100**, the recording unit **100** causes the ink-jet head **10** to discharge ink droplets based on the data to be printed while moving the carriage **21** in the main scanning direction at the timing at which the conveyance of the sheet Q is stopped. Accordingly, the recording unit **100** forms the image in the main scanning direction on the sheet Q.

Upon receipt of the data to be printed by the main unit **40**, the main unit **40** causes the feed unit **50** to supply the sheet Q to the nip position as described above. Next, the main unit **40** sets a target conveyance amount Yr of the sheet Q and causes the sheet conveyance unit **60** to convey the sheet Q to the first image formation position corresponding to the target conveyance amount Yr. After that, the main unit **40** controls the recording unit **100** to move the carriage **21** one way in the main scanning direction and to form the image corresponding to the one-way movement onto the sheet Q.

Then, the main unit **40** controls the sheet conveyance unit **60** to convey the sheet Q to the second image formation position corresponding to the target conveyance amount Yr. After that, the main unit **40** controls the recording unit **100** to move the carriage **21** one way in the main scanning direction and to form the image corresponding to the one-way movement onto the sheet Q. The main unit **40** causes the sheet conveyance unit **60** and the recording unit **100** to perform the above processes alternately so as to form the image based on the data to be printed on the sheet Q.

Subsequently, a detailed structure of the sheet conveyance unit **60** will be explained. As depicted in FIG. **2**, the sheet conveyance unit **60** includes the conveyance mechanism **30**, the PF motor **61**, a motor drive circuit **65**, a rotary encoder **70**, a signal processing circuit **80**, and a controller **90**.

As described above, the conveyance mechanism **30** includes the conveyance roller **31**, the driven roller **32**, the discharge roller **35**, the driven roller **36**, the connection mechanism **38**, and the platen **39** (not depicted in FIG. **2**). The conveyance roller **31** and the discharge roller **35** are connected via the connection mechanism **38** to rotate in synchronization with each other. The conveyance mechanism **30** conveys the sheet Q in the sheet conveyance direction by rotating the conveyance roller **31** and the discharge roller **35** upon receipt of the power from the PF motor **61**. The conveyance roller **31** is connected to the PF motor **61** via the gear.

The PF motor **61** is driven by the motor drive circuit **65** to rotate the conveyance roller **31**. The motor drive circuit **65** drives the PF motor **61** by applying a drive current (or a drive voltage), which corresponds to an operation amount U inputted from the controller **90**, to the PF motor **61**.

The rotary encoder **70** is provided to observe rotation of the conveyance roller **31**. Like well-known rotary encoders, the rotary encoder **70** includes a disk **71** formed with a scale **71**A and an optical sensor **75** reading the scale **71**A. As depicted in FIG. **3**, the disk **71** is fixed to the conveyance roller **31**.

The scale **71**A is formed as a plurality of slits which are aligned to be concentric with the disk **71** inside the circumference of the disk **71** at regular intervals. The disk **71** of this embodiment is fixed to an end of the conveyance roller **31** so that the center Oe of the disk **71** is disposed at a position deviated from a rotational axis Or of the conveyance roller **31**. That is, the disk **71** is fixed to the end of the conveyance roller **31** in a state of being eccentric to the rotational axis Or of the conveyance roller **31**.

The optical sensor **75** is arranged at an area, in the casing of the image forming system **1**, over which the scale **71**A passes. The optical sensor **75** outputs pulse signals every time each slit formed in the disk **71** passes over the optical sensor **75**. The passage of each of the slits over the optical sensor **75** is caused by rotation of the disk **71** associated with rotation of the conveyance roller **31**. That is, the optical sensor **75** outputs, as the pulse signals, an A-phase encoder signal and a B-phase encoder signal having a phase which is different from that of the A-phase encoder signal by $\pi/2$, every time each slit passes over the optical sensor **75**.

The rotary encoder **70** of this embodiment is a well-known two-phase rotary encoder which is attached to the conveyance roller **31** in a state of being eccentric thereto. The rotary encoder **70** causes the optical sensor **75** to read the scale **71**A formed in the disk **71** during rotation of the disk **71** and outputs the A-phase and B-phase encoder signals depending on the rotation of the disk **71**.

The signal processing circuit **80** detects a rotation position X and a rotation velocity V of the disk **71** based on the A-phase and B-phase encoder signals from the rotary encoder **70** to input them to the controller **90**. Specifically, in a case that the disk **71** rotates in a forward direction, the signal processing circuit **80** increments a count value X every time the pulse edge of each of the A-phase and B-phase encoder signals is detected. In a case that the disk **71** rotates in a reverse rotation, the signal processing circuit **80** decrements the count value X every time the pulse edge of each of the A-phase and B-phase encoder signals is detected. The signal processing circuit **80** inputs the count value X to the controller **90** as the rotation position X.

The signal processing circuit **80** measures the time interval between pulse edges of the A-phase encoder signal or the B-phase encoder signal. A value corresponding to a reciprocal of the time interval between pulse edges is inputted to the controller **90** as the rotation velocity V of the disk **71**.

In addition to the above, the controller **90** includes a target setting unit **91**, a position controller **93**, and an origin setting unit **95**. The target setting unit **91** sets a target stop position Xr, which corresponds to the target conveyance amount Yr designated by the main unit **40**, in the position controller **93**.

The position controller **93** inputs the operation amount U to the motor drive circuit **65**, the operation amount U corresponding to a deviation E=Xr−X between the target stop position Xr set by the target setting unit **91** and the rotation position X obtained from the signal processing circuit **80**. With this, the position controller **93** controls the PF motor **61** so that rotation of the conveyance roller **31** stops at a point at which the rotation position X is coincident with the target stop position Xr. That is, the position controller **93** controls the PF motor **61** so that the rotation position X detected by the signal processing circuit **80** is coincident with the target stop position Xr, thereby controlling the rotation of the conveyance roller **31** and the amount of conveyance of the sheet Q.

The origin setting unit **95** specifies a position-phase relation, which is a correspondence relation between the rotation position X of the disk **71** and the rotation phase θ of the conveyance roller **31**, based on the rotation position X and the rotation velocity V those of which are obtained when the position controller **93** controls the PF motor **61** to rotate the conveyance roller **31** at a constant velocity. The origin setting unit **95** sets an origin position X**0** based on the specified position-phase relation. Since the disk **71** is fixed to the conveyance roller **31**, the rotation position X of the disk **71** can be also referred to as the rotation position X of the conveyance roller **31**, and the rotation phase θ of the disk **71** can be also referred to as the rotation phase θ of the conveyance roller **31**.

Specifically, the origin setting unit **95** generates velocity data which indicates a locus of the rotation velocity V with respect to the rotation position X obtained when the conveyance roller **31** rotates at a constant velocity. Then, the origin setting unit **95** specifies the position-phase relation based on variation of the locus indicated by the velocity data.

FIG. **4** is a graph indicating a relation between the rotation position X of the disk **71** and the rotation velocity V of the disk **71** during a period of time in which the conveyance roller **31** rotates at a constant velocity. The left end area of FIG. **4** is a locus of the velocity V during an acceleration section where the rotation velocity V has not yet reached a constant velocity Vc as the target velocity. As understood from FIG. **4**, the rotation velocity V during a constant velocity section includes a velocity component which varies with respect to the rotation position X in accordance with a period corresponding to the rotation period of the conveyance roller **31** and the disk **71**.

The reason why, even though the rotation velocity of the conveyance roller **31** is controlled to be constant, the rotation velocity V during the constant velocity section includes the varying velocity component is as follows. That is, the disk **71** is attached to the conveyance roller **31** in a state of being eccentric to the rotational axis of the conveyance roller **31**. FIG. **5** depicts variation of the disk center Oe between a time T**1** and a time T**2** brought about when the conveyance roller **31** rotates at an angular velocity ω. In FIG. **5**, the rotational axis Or of the conveyance roller **31** is away from the disk center Oe by a distance Δr. In this case, the disk center Oe is displaced, associated with rotation of the conveyance roller **31**, to move along the arc of a radius Δr (along the one dot chain line of FIG. **5**) of which center is the rotational axis Or of the conveyance roller **31**.

The broken line depicted in FIG. **5** conceptually indicates the arrangement of the scale **71**A (alignment of the slits) at the time T**2**, and the bold solid line depicted in FIG. **5** conceptually indicates the circumference of the disk **71** at the time T**2**. Meanwhile, the two dot chain lines depicted in FIG. **5** conceptually indicates the circumference of the disk **71** at the time T**1**. In FIG. **5**, the distance Δr is depicted longer than the actual distance. In a case that the distance Δr is long, the variation of the disk **71** is large. This might cause such a problem that the optical sensor **75** cannot read the scale **71**A. In order to prevent this problem, the distance Δr is set appropriately or suitably in this embodiment.

As depicted in FIG. **5**, in a case that the conveyance roller **31** rotates between the time T1 and the time T**2** by an angle Δθ=ω(T**2**−T**1**), the variation amount of the scale **71**A brought about when the disk center Oe is coincident with the rotational axis Or is different from the variation amount of the scale **71**A brought about when the disk center Oe is not coincident with the rotational axis Or by a distance ΔL.

The variation of the rotation velocity V depicted in FIG. **4** is brought about by the distance ΔL. This variation is geometrically defined according to positions of the rotational axis Or, the disk center Oe, and the optical sensor **75**. For example, the variation is caused by displacement of the disk center Oe parallelly to and perpendicularly to a displacement direction of each slit passing over the optical sensor **75**. Thus, obtaining the correspondence relation between the phase θ of the varying velocity component and the rotation position X results in obtaining the correspondence relation between the rotation phase θ and the rotation position X of the conveyance roller **31**. In this embodiment, the position-phase relation is specified by use of this principle.

Specifically, the origin setting unit **95** searches a sinusoidal wave, which matches the locus of the rotation velocity V observed by the rotary encoder **70**, while changing an initial phase of a sinusoidal wave having a period which is coincident with the rotation period of the conveyance roller **31**. Then, the origin setting unit **95** specifies the position-phase relation based on the relation between the rotation position X and the initial phase of the sinusoidal wave which matches the locus.

Here, an origin setting process, which is executed by the origin setting unit **95** according to the command from the main unit **40**, will be explained by use of FIGS. **6**A and **6**B. The main unit **40** inputs an origin setting command to the controller **90** when the image forming system **1** is switched on. The origin setting unit **95** starts the origin setting process in accordance with this command.

In a case that the origin setting process is started, the origin setting unit **95** starts the control of the PF motor **61** to rotate the conveyance roller **31** at a constant velocity (S**110**). Specifically, the origin setting unit **95** calculates the operation amount U for the PF motor **61** and inputs the calculated operation amount U to the motor drive circuit **65**. Accordingly, the origin setting unit **95** controls the PF motor **61** to rotate the conveyance roller **31** at the constant velocity.

In this context, the PF motor **61** can be controlled to rotate the conveyance roller **31** at the constant velocity by performing a feedback control based on the rotation velocity V obtained from the signal processing circuit **80**. In this case, however, the sensitivity of the feedback control is required to be low so that the feedback control never interferes with the variation of the rotation velocity V due to the eccentricity. Instead of the feedback control, the PF motor **61** can be controlled to rotate the conveyance roller **31** at the constant velocity by performing a feedforward control.

After the rotation of the conveyance roller **31** is started at S**110**, the origin setting unit **95** waits until the conveyance roller **31** rotates at the constant velocity. Then, the origin setting unit **95** stores, based on the rotation position X and the rotation velocity V inputted from the signal processing circuit **80**, the rotation velocity V while being correlated with the rotation position X, every time the rotation position X increases, during the constant velocity section in which the conveyance roller **31** rotates at the constant velocity. Accordingly, the origin setting unit **95** generates velocity data indicating the relation between the rotation position X and the rotation velocity V during the constant velocity section (S**120**).

The origin setting unit **95** generates velocity data indicating the relation between the rotation position X and the rotation velocity V during a period in which the conveyance roller **31** turns at least one revolution at the constant velocity. In order to specify the position-phase relation with high accuracy, it is preferred that the velocity data be generated by storing the rotation position X and the rotation velocity V while being correlated with each other over a sufficient time longer than the rotation period of the conveyance roller **31**.

In a case that the generation of velocity data in the constant velocity section is completed, the origin setting unit **95** completes the drive of the PF motor **61** started at S**110** (S**130**). Then, the origin setting process proceeds to S**140**. At S**140**, the origin setting unit **95** removes a direct-current component from the locus of the rotation velocity V indicated by the generated velocity data. For example, in a case that the PF motor **61** is controlled to rotate the conveyance roller **31** at the constant rotation velocity V=Vc, the locus of the rotation velocity V indicated by the velocity data shows the waveform of which amplitude center is the constant rotation velocity V=Vc (see FIG. **4**). At S**140**, the origin setting unit **95** removes the direct-current component from the locus of the rotation velocity V, and the origin setting unit **95** processes the velocity data so that the amplitude center of the locus of the rotation velocity V is zero.

Specifically, the origin setting unit **95** calculates an average value VA of the rotation velocity V indicated by the velocity data at S**140**. Then, the origin setting unit **95** removes the direct-current component from the locus of the rotation velocity V by subtracting the average value VA from the rotation velocity V at each rotation position X which is indicated by the velocity data.

After that, the origin setting unit **95** generates, based on the velocity data from which the direct-current component is removed, a vector H=(V[1], . . . , V[N]) of the velocity data (S**150**). The vector H includes, as elements, a plurality of rotational velocities V at a plurality of rotation positions X which are indicated by the velocity data from which the direct-current component is removed. The rotational velocities V are aligned in ascending order of the rotation position X. In this context, "N" means the number of samples of rotational velocities V included in the velocity data.

After S**150**, the origin setting unit **95** sets a variable k to 1 (S**160**), and the origin setting unit **95** sets an initial phase P of the sinusoidal wave according to the equation of P=(k−1)·dP (S**170**). The unit of the initial position P used herein is not radian but the same unit as the rotation position X. The constant dP corresponds to a deviation amount of the initial phase P and the constant dP can be determined, for example, to have a value 1. The constant dP, however, may be determined to have a value greater than 1. The value of the constant dP can be determined appropriately. The calculation amount is smaller as the value of the constant dP is greater. In order to specify the origin position X**0** with high accuracy, it is preferred that dP be smaller.

Then, the origin setting unit **95** generates a vector W=(W[1], . . . , W[n]) which indicates the sinusoidal wave of the initial phase P (S**180**). An element W[n] of the vector W (n=1, . . . , N) is represented by the following equation.

$$W[n]=\sin\{2\pi\cdot\{(n-1)-P\}/Xc\}$$

In this equation, the value Xc is the increment of the rotation position X brought about when the disk **71** turns one revolution. That is, the value Xc indicates the variation amount of the rotation position X brought about when the disk **71** turns one revolution, in other words, brought about when the conveyance roller **31** turns one revolution. The value Xc is a fixed value and the value Xc can be stored in the origin setting unit **95** or the ROM **43** in advance. In a case that the initial phase P is 0, the vector W of the sinusoidal wave of which phase is 0 is generated at a rotation position Xh corresponding to the element V[1] of the vector H.

As another example, at S**120**, the origin setting unit **95** may generate velocity data while correlating the rotation position X with the rotation velocity V those of which are inputted from the signal processing circuit **80** every sampling period which is defined in advance to be longer than the time in which the rotation position X is increased by one. In this case, at S**180**, it is possible to generate, as the vector W of the sinusoidal wave, the vector W which includes, as the element, the value of the sinusoidal wave at each rotation position X corresponding to each element of the vector H.

After that, the origin setting unit **95** calculates an inner product Z=<H,W> of the vector H and the vector W, and the origin setting unit **95** stores the inner product Z while correlating the inner product Z with the value of the variable k (S**190**). Then, the origin setting unit **95** judges whether or not the initial phase P is deviated by an amount corresponding to one revolution (S**200**). Specifically, the origin setting unit **95** judges whether or not k≥(Xc/dP) is held. Here, in a case that the origin setting unit **95** judges that k<(Xc/dP) is held (S**200**: No), the origin setting unit **95** increments the variable k by one (S**210**). Then, the origin setting process returns to S**170**.

In a case that the process returns to S**170**, the origin setting unit **95** sets the initial phase P based on the variable k after the increment. At S**180**, the vector W of the sinusoidal wave is generated by deviating the most recent initial phase P by an amount corresponding to dP. At S**190**, the inner product Z of this vector W and the vector H based on the velocity data from which the direct-current component is removed is calculated and the inner product Z is stored while being correlated with the value of the variable k.

By repeatedly performing the process ranging from S**170** to S**210**, the origin setting unit **95** calculates the inner product Z of the sinusoidal wave and the locus indicated by the velocity data while deviating the initial phase P by the amount corresponding to dP as depicted in FIG. **7**A. In a case that the origin setting unit **95** judges that the initial phase is deviated by the amount corresponding to one revolution (S**200**: Yes), the origin setting unit **95** performs the process of S**220**.

At S**220**, the origin setting unit **95** specifies the inner product Z having a maximum value from among the inner products Z corresponding to one revolution, and the origin setting unit **95** specifies a value k=Km of the variable k corresponding to the inner product Z having the maximum value (S**220**). The maximum value of the inner product Z is brought about when the phase of the sinusoidal wave matches the phase of variation component of the rotation velocity V as depicted in FIG. **7**B. After that, the origin setting unit **95** sets, as the origin position X**0** of the rotation position X, a value which is obtained by being deviated from the rotation position Xh corresponding to the element V[1] of the vector H by an amount of $\{(Km-1)\cdot dP\}$ (S**230**). That is, $Xh+\{(Km-1)\cdot dP\}$ is set as the origin position X**0** (S**230**). This origin position X**0** corresponds to a point at which the phase of the sinusoidal wave, which makes the value of inner product Z maximum, is zero. After that, the origin setting unit **95** completes the origin setting process.

Subsequently, an explanation will be made about a target correction process executed by the target setting unit **91** with reference to FIGS. **8**A, **8**B and FIG. **9**. The target correction process indicated in FIGS. **8**A and **8**B includes steps for correcting the target stop position Xr of the conveyance roller **31** which corresponds to the target conveyance amount Yr of the sheet Q designated by the main unit **40** (i.e., the target stop position Xr=Xr**0** in which the eccentricity of the disk **71** is not taken into consideration).

Upon receipt the target conveyance amount Yr and the conveyance command of the sheet Q from the main unit **40**, the target setting unit **91** executes the target correction process. Specifically, the target setting unit **91** corrects the target stop position Xr corresponding to the target conveyance amount Yr from the target stop position Xr=Xr**0** in which the eccentricity of the disk **71** is not taken into consideration. The position controller **93** controls the PF motor **61** based on the target stop position Xr corrected by the target setting unit **91**. Accordingly, the conveyance roller **31** is rotated to reach the target stop position Xr, thereby conveying the sheet Q by the target conveyance amount Yr.

In a case that the disk **71** is attached to the conveyance roller **31** such that the disk center Oe is coincident with the rotational axis Or of the conveyance roller **31** like conventional apparatuses, a sheet conveyance amount dY, brought about when the rotation position X of the disk **71** is increased by one, ideally stays constant. Thus, in order to convey the sheet Q by the target conveyance amount Yr, the target stop position Xr may be set to Xs+(Yr/dY) based on a conveyance start position X=Xs. In this context, Xs indicates the rotation position X at the time of starting the conveyance of the sheet Q. Accordingly, the sheet Q can be conveyed by the target conveyance amount Yr.

In this embodiment, however, the disk **71** is attached to the rotational axis Or of the conveyance roller **31** in a state of being eccentric thereto. In this case, a sheet conveyance amount dY(θ) brought about when the rotation position X of the disk **71** is increased by one varies according to the rotation phase θ of the disk **71**. FIG. **9** is a graph indicating a conveyance deviation amount δ(θ) of the sheet Q when the disk center Oe is attached to the conveyance roller **31** in a state of being eccentric thereto.

In FIG. **9**, the horizontal axis represents the rotation position X. The relation between the rotation phase θ ($0\leq\theta<2\pi$) and the rotation position X can be represented by the equation of $\theta=2\pi\cdot(X-X0)/Xc$ using the origin position X**0**. In a case that the disk **71** has the eccentricity, the sheet conveyance amount dY(θ) brought about when the disk **71** is rotated from the rotation phase θ to increase the rotation position X by one can be represented by the equation of $dY(\theta)=dY+\delta(\theta)$. That is, the conveyance deviation amount δ(θ) indicated in FIG. **9** represents a value $\{dY(\theta)-dY\}$ obtained by subtracting the sheet conveyance amount dY brought about when the disk **71** has no eccentricity from the sheet conveyance amount dY(θ) brought about when the disk **71** has the eccentricity.

As described above, the origin position X**0** corresponds to the rotation position X of when the variation component of the rotation velocity V crosses the amplitude center in the forward direction. That is, in a case that the rotation phase θ ranges from 0 to π, a rotation velocity V to be measured is indicated to be greater than an actual velocity due to the eccentricity. This means that an apparent sheet conveyance amount calculated from the rotation position X is greater than an actual sheet conveyance amount in the case that the rotation phase θ ranges from 0 to π. Therefore, the conveyance deviation amount δ(θ) indicated in FIG. **9** adopts a negative value in the case that the rotation phase θ ranges from 0 to π.

As indicated in FIG. **9**, the conveyance deviation amount δ(θ) of the sheet Q brought about when the rotation phase θ is increased by (2π/Xc) corresponding to one unit of the rotation position X is represented by the equation of $\delta(\theta)=-A\cdot\sin(\theta)$. The amplitude A (>0) represents the apparent conveyance amount of the sheet Q which corresponds to the amount of variation of the rotation position X of when the disk center Oe is displaced in the displacement direction of the slit passing the optical sensor **75**. The amplitude A can be obtained by desk calculation or actual measurement, and can be stored in the target setting unit **91** or the ROM **43** in advance.

In a case that the relation between the conveyance deviation amount δ(θ) and the rotation phase θ is held as described above, a conveyance error Ye of the sheet Q from the conveyance start position X=Xs of the sheet Q to the target stop position Xr of the sheet Q corresponds to the hatched area depicted in FIG. **9**, and the conveyance error Ye can be represented by the following expression.

$$Ye=-\sum_{X=Xs}^{Xs+Xr} A\cdot\sin\left\{\frac{2\pi}{Xc}(X-X0)\right\} \tag{1}$$

The conveyance error Ye indicates a conveyance amount, which is increased from the sheet conveyance amount $Y=dY\cdot(Xr-Xs)$ within the range from the rotation position X=Xs to the target position Xr in a case that the eccentricity is not taken into consideration. In the target correction process depicted in FIGS. **8**A and **8**B, the target stop position Xr which corresponds to the target conveyance amount Yr designated by the main unit **40** is set to the target stop position Xr=Xr**0**=Xs+Yr/dY which is supposed to have no eccentricity. The target stop position Xr=Xr**0** is corrected by an amount corresponding to the conveyance error Ye to calculate the target stop position Xr for conveying the sheet Q by the target conveyance amount Yr.

Specifically, in a case that the target correction process is started, the target setting unit **91** sets the target stop position Xr which corresponds to the target conveyance amount Yr designated by the main unit **40** to the target stop position Xr=Xr**0**=Xs+Yr/dY in which the eccentricity of the disk **71** is not taken into consideration (S**210**). After that, the target setting unit **91** sets the target stop position Xr to Xr**0** in accordance with the expression (1), and calculates the conveyance error (increment) Ye, of the sheet conveyance amount Y, from the target conveyance amount Yr at the time of driving the PF motor **61** (S**220**).

Next, the target setting unit **91** judges whether or not the calculated conveyance error Ye is zero (S**230**). In a case that the target setting unit **91** judges that the calculated conveyance error Ye is zero (S**230**: Yes), the target setting unit **91** completes the target correction process without any correction for the target stop position Xr.

In a case that the target setting unit **91** judges that the conveyance error Ye is not zero (S**230**: No), the target setting unit **91** judges whether or not the conveyance error Ye is a positive or plus (S**240**). In a case that the target setting unit **91** judges that the conveyance error Ye is the positive (S**240**: Yes), the target setting unit **91** performs the process of S**250**.

At S**250**, the target setting unit **91** sets a variable j to zero. Further, the target setting unit **91** sets the conveyance error Ye calculated at S**220** as a conveyance error Ya (S**260**). After that, the target setting unit **91** executes processes subsequent to S**270**.

At S**270**, the target setting unit **91** calculates an error variation amount ΔY[j] in accordance with the following expression. The error variation amount ΔY[j] is a variation amount of the conveyance error Ya obtained by reducing the target stop position Xr from (Xr**0**−j) to (Xr**0**−(j+1)). As described above, dY is a sheet conveyance amount brought about when the rotation position X is increased by one in a state that the disk **71** has no eccentricity.

$$\Delta Y[j]=dY-A\cdot\sin\{2\pi\cdot(Xr0-j-X0)/Xc\}$$

After that, the target setting unit **91** updates the conveyance error Ya to a value obtained by subtracting the value ΔY[j] from the current conveyance error Ya (Ya←Ya−ΔY[j]).

The target setting unit **91** judges whether or not the updated conveyance error Ya is zero or less (S**290**). In a case that the target setting unit **91** judges that the updated conveyance error Ya is more than zero (S**290**: No), the target setting unit **91** updates the valuable j to a value to which one is added, and executes the process of S**270** (S**300**). Accordingly, the conveyance error Ya from the target conveyance amount Yr which is obtained by reducing the target stop position Xr to make the conveyance error Ya zero or less, is calculated in steps.

In a case that the target setting unit **91** judges that the conveyance error Ya is zero or less (S**290**: Yes), the target setting unit **91** corrects the target stop position Xr to Xr={Xr**0**−(j+1)} (S**310**) and completes the target correction process.

Meanwhile, in a case that the target setting unit **91** judges at S**240** that the conveyance error Ye is a minus or negative (S**240**: No), the target setting unit **91** sets the variable j to −1 (S**320**). Further, the target setting unit **91** sets the conveyance error Ye calculated at S**220** as the conveyance error Ya (S**330**). After that, the target setting unit **91** executes processes subsequent to S**340**.

At S**340**, the target setting unit **91** calculates an error change amount ΔY[j] in accordance with the following expression. The error variation amount ΔY[j] is a variation amount of the conveyance error Ya which is obtained by increasing the target stop position Xr from (Xr**0**−(j+1)) to (Xr**0**−j).

$$\Delta Y[j]=dY-A\cdot\sin\{2\pi\cdot(Xr0-j-X0)/Xc\}$$

After that, the target setting unit **91** updates the conveyance error Ya to a value obtained by adding the value ΔY[j] to the current conveyance error Ya (Ya←Ya+ΔY[j]) (S**350**).

The target setting unit **91** judges whether or not the updated conveyance error Ya is zero or more (S**360**). In a case that the target setting unit **91** judges that the updated conveyance error Ya is less than zero (S**360**: No), the target setting unit **91** updates the valuable j to a value from which one is subtracted, and executes the process of S**340** (S**370**). Accordingly, the conveyance error Ya from the target conveyance amount Yr which is obtained by increasing the target stop position Xr to make the conveyance error Ya zero or more, is calculated in steps.

In a case that the target setting unit **91** judges that the conveyance error Ya is zero or more (S**360**: Yes), the target setting unit **91** corrects the target stop position Xr to Xr=(Xr**0**−j) (S**380**), and completes the target correction process.

After completion of the target correction process, the target setting unit **91** further corrects the target stop position Xr which has been corrected in the target correction process while taking into consideration the conveyance error of the sheet Q caused by a factor other than the eccentricity of the disk **71** to the conveyance roller **31**. Then, the target setting unit **91** sets the corrected target stop position Xr in the position controller **93**.

For example, the target setting unit **91** further corrects the target correction position Xr by using a known technology to clear the conveyance error caused by the deviation of the rotational axis Or of the conveyance roller **31** from the center. Then, the target setting unit **91** may set the target stop position Xr after this correction in the position controller **93**. This correction needs information of the rotation phase θ of the conveyance roller **31**. As the information of the rotation phase θ of the conveyance roller **31**, it is possible to use the correspondence relation between the rotation phase θ and the rotation position X of the disk **71** specified by the origin setting unit **95**.

It is noted that the conveyance error caused by the deviation of the rotational axis Or of the conveyance roller **31** from the center can be substantially cleared or removed by adjusting the amplitude A of the expression (1) and the initial phase in the sine function of the expression (1) those of which are used in the target correction process, without any further correction for the target stop position Xr which has been corrected in the target correction process. This is because the vibration component caused by this deviation has the same frequency as that of the vibration component caused by the eccentricity of the disk **71**.

Therefore, the target setting unit **91** can achieve the conveyance of the sheet Q with high accuracy by setting the target stop position Xr, which has been corrected in the target correct process, in the position controller **93** to prevent the conveyance error caused by the eccentricity of the conveyance roller **31** without any further correction. The adjustment of the amplitude A and the initial phase for which the eccentricity of the conveyance roller **31** is taken into consideration can be performed based on, for example, the result of test printing.

In the above description, the image forming system **1** according to this embodiment has been explained. In this embodiment, the disk **71** of the rotary encoder **70** is provided in a state of being eccentric to the rotational axis Or of the conveyance roller **31** purposefully. This causes the variation corresponding to the rotation period of the disk **71** in the locus of the rotation velocity V with respect to the rotation position X. The phase θ of the variation component corresponds to the rotation phase θ of the disk **71** and the rotation phase θ of the conveyance roller **31**. In this embodiment, the relation between the phase θ of the variation component and the rotation position X is obtained to define the rotation position X of when the phase θ of the variation component is zero as the origin position X**0**. That is, the position-phase relation between the rotation position X and the rotation phases θ of the conveyance roller **31** and the disk **71** is specified to $\theta-2\pi\sim(X-X0)/Xc$, and subsequent motor control (conveyance control of the sheet Q) is performed based on this relation.

According to this embodiment, unlike conventional encoder disks, it is not necessary to provide any dedicated sensor or structure for detecting the origin. Thus, it is possible to reduce the number of components and production costs. Further, since it is possible to specify the position-phase relation and to set the origin with high accuracy, it is possible to control at least one of the rotation of the conveyance roller **31** and the displacement (conveyance) of the sheet Q which is displaced by the action or effect from the conveyance roller **31** with high accuracy.

In this embodiment, the velocity data is generated while the conveyance roller **31** is rotated at a constant velocity. Then, the process for removing the direct-current component from the velocity data is performed. That is, the component, which is not required for specifying the position-phase relation, is removed from the velocity data. Therefore, it is possible to specify the position-phase relation and to set the origin position with higher accuracy.

In this embodiment, the position-phase relation is specified as follows. That is, the phase θ, of the sinusoidal wave having the same period as the rotation period of the conveyance roller **31** and matching the velocity locus indicated by the velocity data, with respect to the rotation position X is detected. The sinusoidal wave matching the velocity locus is a sinusoidal wave having the same period as the rotation period of the conveyance roller **31** and having the maximum value of the inner product of the sinusoidal wave and the velocity locus from which the direct-current component is removed. The position-phase relation is specified based on the initial phase P of such a sinusoidal wave. Therefore, according to this embodiment, it is possible to specify the position-phase relation and to set the origin position with high accuracy by performing the simple calculation process concerning the velocity data such as the calculation of the inner product and the detection of the maximum value.

According to this embodiment, the target stop position Xr is corrected to make the conveyance error Ye zero based on the corresponding relation between the rotation phase θ and the sheet conveyance amount $\Delta Y=dY-A\cdot\sin\theta$ brought about when the conveyance roller **31** is varied from the rotational phase θ by an amount corresponding to one unit of the rotation position X. Therefore, according to this embodiment, the target stop position Xr corresponding to the target conveyance amount Yr can be set easily and appropriately to control the conveyance amount of the sheet Q with high accuracy.

In the above description, the explanation has been made about the embodiment of the present teaching. The present teaching, however, is not limited to the embodiment and the present teaching can adopt various aspects. For example, the processes achieved by the controller **90** may be achieved with hardware or software.

In the above embodiment, the point at which the phase of the sinusoidal wave matching the variation component of the rotation velocity V is zero is set as the origin position X**0**. However, a point at which the phase of the sinusoidal wave is other than zero may be set as the origin position X**0**. For

example, a point at which the phase of the sinusoidal wave is π may be set as the origin position X**0** or a point which is convenient for the calculation of the conveyance error Ye may be set as the origin position X**0**.

In the above embodiment, the sinusoidal wave matching the velocity locus indicated by the velocity data is searched by the calculation of the inner product of the vector H of the rotation velocity V and the vector W of the sinusoidal wave having a different initial phase P. The phase of the velocity locus indicated by the velocity data, however, can be obtained by using other technologies.

In addition to the above, the present teaching can be applied to various control apparatuses each of which controls at least one of the rotation of a driving body by a motor and the displacement of an object which is displaced by the action or effect from the driving body.

The correspondence or correlation between the terms is as follows. The conveyance roller **31** is an exemplary driving body; the sheet Q is an exemplary object which is displaced by the action or effect from the driving body; the signal processing circuit **80** is an exemplary detector; the controller **90** is an exemplary controller. In addition to the above, the process ranging from S**110** to S**130** executed by the origin setting unit **95** is an exemplary data generation process; the process of S**140** is an exemplary removal process; and the process ranging from S**150** to S**230** is an exemplary phase specifying process. The processes executed by the target setting unit **91** and the position controller **93** are examples of a main control process. The expression for calculating the error variation amount ΔY is an exemplary conveyance amount correspondence relation.

What is claimed is:

1. A control apparatus comprising:

a motor;

a driving body configured to rotate around a rotational axis by the motor;

a rotary encoder including a disk and a sensor, the disk being fixed to the driving body in a state of being eccentric to the rotational axis of the driving body; and being configured to rotate with the driving body, and the sensor being configured to read a scale of the disk and to output a pulse signal depending on rotation of the disk;

a detector configured to detect a rotation position and a rotation velocity of the disk based on the pulse signal outputted from the sensor; and

a controller,

wherein the controller is configured to perform:

a data generation process of controlling the motor to make the driving body turn at least one rotation and generating velocity data based on the rotation position and the rotation velocity of the disk which are detected by the detector during the at least one rotation of the driving body, the velocity data indicating a locus of the rotation velocity with respect to the rotation position;

a phase specifying process of specifying a position-phase relation, which is a correspondence relation between the rotation position of the disk and a rotation phase of the driving body, by detecting a phase, of a periodic velocity component of the locus indicated by the velocity data with respect to the rotation position of the disk, the phase of the periodic velocity component corresponding to the rotation phase of the driving body; and

a main control process of controlling at least one of the rotation of the driving body and displacement of an object, which is displaced by action from the driving body, by driving the motor based on the position-phase relation specified by the phase specifying process.

2. The control apparatus according to claim **1**, wherein in the data generation process, the controller is configured to:

control the motor to rotate the driving body at a constant velocity; and

generate the velocity data indicating the locus during the rotation of the driving body at the constant velocity.

3. The control apparatus according to claim **2**, wherein in the phase specifying process, the controller is configured to specify the position-phase relation by detecting a phase of a sinusoidal wave with respect to the rotation position, the sinusoidal wave having the same period as the rotation period of the driving body and matching the locus.

4. The control apparatus according to claim **3**, wherein in the phase specifying process, the controller is configured to:

search a sinusoidal wave, which has the same period as the rotation period of the driving body and which makes an inner product of the sinusoidal wave and the locus maximum, as the sinusoidal wave matching the locus, while deviating an initial phase of the sinusoidal wave; and

specify the position-phase relation based on the initial phase of the sinusoidal wave which makes the inner product maximum.

5. The control apparatus according to claim **2**,

wherein the controller is configured to further perform a removal process of removing a direct-current component from the locus indicated by the velocity data, and

in the phase specifying process, the controller is configured to detect the phase based on the locus from which the direct-current component is removed in the removal process.

6. The control apparatus according to claim **5**, wherein in the removal process, the controller is configured to:

calculate an average value of a plurality of rotation velocities at a plurality of rotation positions, the rotation velocities constituting the locus; and

remove the direct-current component from the locus by subtracting the average value from each of the rotation velocities.

7. The control apparatus according to claim **6**,

wherein in the data generation process, the controller is configured to generate the velocity data in which the rotation velocities are correlated with the rotation positions respectively,

in the removal process, the controller is configured to generate velocity data after removal of the direct-current component by removing the direct-current component from each of the rotation velocities constituting the locus, and

in the phase specifying process, the controller is configured to detect a phase of a sinusoidal wave matching the locus with respect to the rotation position of the disk, by repeatedly performing a process of calculating an inner product of the sinusoidal wave and the locus indicated by the velocity data, from which the direct-current component is removed, while deviating an initial phase of the sinusoidal wave over a range of the rotation position which corresponds to at least one rotation of the driving body.

8. The control apparatus according to claim **1**,

wherein the driving body is a roller configured to convey a sheet in a direction perpendicular to the rotational axis of the roller, and

in the main control process, the controller is configured to:

set a target value of the rotation position which corresponds to a target conveyance amount of the sheet, based on the position-phase relation; and

control the motor so that the rotation position detected by the detector is varied to have the target value, thereby conveying the sheet by the target conveyance amount.

9. The control apparatus according to claim **8**,

wherein the controller is configured to store a conveyance amount correspondence relation which is a correspondence relation between a rotation phase of the roller and a conveyance amount of the sheet, which is brought about under a condition that the roller rotates from the rotation phase by an amount corresponding to one unit of the rotation position of the disk, and

in the main control process, the controller is configured to set the target value corresponding to the target conveyance amount of the sheet by specifying a conveyance amount of the sheet over a range from an initial position, which is the rotation position of the disk at the time of starting conveyance of the sheet, to the target value, based on the position-phase relation and the conveyance amount correspondence relation.

10. The control apparatus according to claim **9**, wherein in the main control process, the controller is configured to:

set, as a temporary target value, the target value of the rotation position of the disk corresponding to the target conveyance amount which is brought about under a condition that the disk is fixed to the driving body in a state that there is no eccentricity to the rotational axis of the driving body; and

set the target value of the rotation position of the disk by correcting the temporary target value according to the conveyance amount correspondence relation so as to make an error between the target conveyance amount and a conveyance amount of the sheet over a range from the initial position to the temporary target value zero.

11. An image forming system comprising:

the control apparatus according to claim **8**, and

an image forming mechanism configured to form an image on the sheet conveyed by the roller of the control apparatus.

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